Description of Analytical Tools

Name: Land Atmosphere Water Simulator (LAWS)

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Availability of Technical Support: A summary of LAWS documentation is available on DWR web site:
http://www.waterplan.water.ca.gov/docs/tools/descriptions/LAWS-description.pdf

Categories: Field-scale water budget, Large Regional scale water supply allocation

Main Features and Capabilities:

- *Daily* time step.
- Spatial scale: smallest unit at Field level for water budget calculations, integrated into larger user-definable (Region) level for water supply allocation.
- The primary purpose of LAWS is to provide water resource managers with an integrated, flexible, and scalable suite of tools for efficiently developing and comparing alternative water management strategies with either historical or forecasted water supply conditions.
- LAWS simulates daily, field-scale land, crop, and water management practices. It provides users with tools to simulate alternative methods for managing soil moisture on a daily basis during the irrigation season based on soil properties, crop type and growth stage.
- Crop transpiration and soil evaporation based on the widely used crop coefficient and reference crop evapotranspiration methods (FAO 56) with modifications to account for actual crop transpiration and soil evapotranspiration.
- LAWS provides users with the capability to evaluate alternative water management strategies based on multiple factors including:
  - Reservoir and conveyance infrastructure
  - Irrigation system characteristics
  - Crop types
  - Soil moisture management practices
  - Delivery priorities
- LAWS simulation results can be used to provide spatially defined water budget information to other models including consumptive use demands, conveyance losses, groundwater pumping, drain water recycling, deep percolation to aquifers, soil water content, reservoir water account balances, district deliveries, and supply shortages.
- LAWS does not solve any governing flow equations except continuity nor is it an optimization model. This approach allows LAWS to be very computationally efficient but it requires the LAWS user to provide key input data from other sources of

information such field studies remote sensing, GIS databases, physical process models, and expert judgment.

- Although LAWS provides users with multiple methods for allocating water supplies and making priority based delivery decisions, LAWS does not employ any mathematical methods to determine what is the "best" allocation of water. In contrast, LAWS provides users with a powerful graphical user interface (GUI) that allows users to readily change water allocation and delivery priorities, land and crop management practices, and infrastructure characteristics to compare the effects of alternative system configurations on reservoir water supplies.
- LAWS has a native GIS capability built directly into the GUI. This GIS capability allows users to setup and analyze spatially accurate LAWS simulations across a span of scales ranging from large regional watersheds to sub-regions contained with individual fields. LAWS also provides users with the capability to import imagery, maps, and GIS information developed with commercially available software packages.
- LAWS has been developed from the Corp of Engineers Water Management System (CWMS) software from which it has inherited a powerful suite of tools to examine model outputs including side by side comparisons of outputs from multiple alternative simulations and animations of spatial and temporal time series results. HEC DSS View is fully integrated into the LAWS interface.
- LAWS user interface has been designed to minimize repetitive data entry and to permit the importation of spatial data in the ESRI shapefile format. The interface also provides context sensitive to assist users with pre- and post-processing tasks.
- LAWS has been linked to a neural network soil parameter estimation model (NeuroMultiStep) to provide users with a tool to readily obtain relevant unsaturated soil parameters from basic soil texture and other characteristics.

Additional Features under Development:

- Additional land use types for simulating municipal and native vegetation water use.
- Capability for simulating effects of groundwater pumping on water table elevation by the method of linear response functions

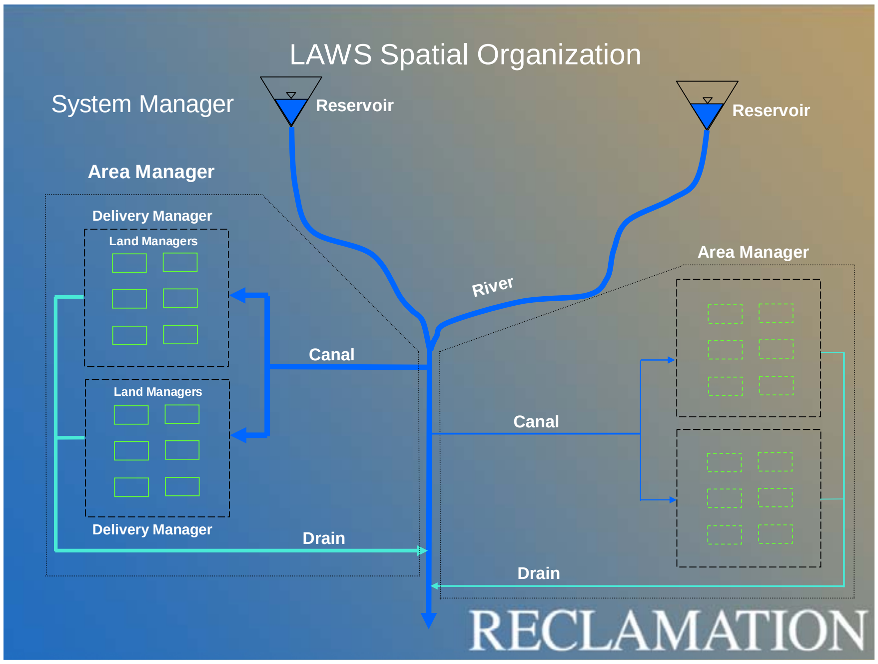
Applications: LAWS has not yet been applied to a real case situation. But it can applied for water budget calculations at the field scale and then integrate the information hierarchically all the way up to the regional level for water supply allocation.

Calibration/Validation/Sensitivity Analysis: No calibration, validation or sensitivity analysis performed yet.

Peer Review: No formal peer review yet.

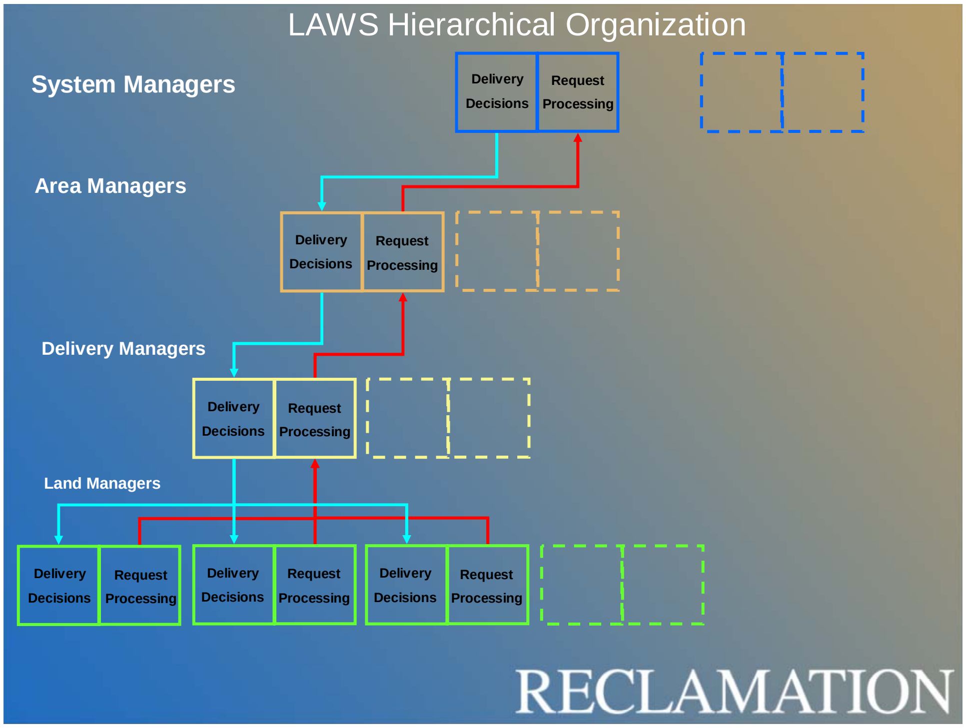
<u>Anatomy of LAWS</u>:

-Conceptual Basis. LAWS captures both the spatial and hierarchical organization of a water supply system. In LAWS, the supply system is conceptualized as a series of nested spatial units that range in size from multi-regional watersheds to individual land units as small as fields. The largest scale land area is associated with a System Manger (SM). In a LAWS simulation, there may be one or more SMs. At the next smaller spatial scale, each Area Manager (AM) manages a particular region within the system. Within these regions, there may be one or more Delivery Managers (DM). These DMs represent sub-regions within the AM region where water management is performed differently based on some unique characteristics of the land or the water supply associated with the sub-region. At the smallest scale, an individual land unit is represented by a Land Manager (LM). Each LM is located within a single DM sub-region. In LAWS, the geospatial locations of major reservoirs, rivers, canals and drains are explicitly located through its GIS capability down to the AM-scale. Although simulated mathematically, smaller scale conveyance infrastructure at the DM- and LM-scales is not explicitly geospatially referenced. The LAWS spatial organization is shown below.



LAWS Spatial Organization

The LAWS hierarchical organization represents the basic structure for managing requests for water supplies and making management decisions necessary for determining the amounts of water to be released from reservoirs as well as the amounts of supply to be provided by groundwater pumping and drain water reuse by individual Land Managers. The LAWS hierarchical organization is presented below.



LAWS Hierarchical Organization

Each SM operates one of more reservoirs which may be located on different rivers systems within a regional watershed. Each reservoir consists of one or more accounts each of which is associated with a specific AM. The volume of water in each AM account is determined by a user specified percentage of the conservation pool. The amount of water in the conservation pool changes in response to reservoir inflows during the course of a simulation. An AM can request deliveries from one or more SM up to the maximum supply in its accounts during the course of a water year.

At each daily time step, the AM is responsible for receiving and accumulating the requests for water supplies from each of its DMs. Using this request information, the AM employs its account utilization methods to determine how much water to request from its various accounts. The amounts of requests are adjusted to account for conveyance depletions/accretions and forwarded to the SMs associated with each of its accounts. The AM also establishes the proportion of the total irrigation demand that will be met with surface water from reservoirs, pumping of groundwater, and the recycling of drain water with the DM sub-regions.

The DM accumulates requests for irrigation water from LMs with its sub-region. The DM adds to this total additional water necessary to account for evaporative and seepage losses from canals and drains within the delivery sub-region. LMs request irrigation water when the soil water content is depleted below a management allowable depletion target.

-Numerical Basis: It is important to recognize that LAWS does not solve the governing equations of flow in open channels. LAWS simulates flow hydraulics and surface-groundwater interactions by using user specified factors. Consequently, the LAWS user must develop this information from field studies, simulations using hydrodynamic and groundwater models, or expert judgment. This simplistic approach used throughout LAWS avoids the computational overhead and complex data requirements of numerical models. However, since LAWS is a mass conservative model, it can be used to determine water budgets from the regional-scale all the way down to the field-scale. Further, the simplicity of the approach permits the LAWS user to efficiently compare alternative land and water management practices, infrastructure characteristics and configurations as well as water delivery priorities explicitly established at each level of the multi-organizational hierarchy.

At each daily time step, the SM manager can use either a sequential or balanced allocation method to determine how much water to release from each of the reservoirs it manages. In a sequential allocation the highest ranking account associated with a particular AM is fully depleted before the next highest ranking account is utilized. In a balanced allocation, water from each reservoir account associated with a particular AM is utilized simultaneously in a user specified proportion. If an account is completely utilized before the simulation is complete, the balance allocation ratios are recomputed to reflect the relative weighting of the accounts that still have remaining water supplies.

The total amount of the SM deliveries must be constrained by the available release capacity of the reservoir and the capacity of the downstream river channels to convey releases without causing flood damages. Since LAWS is intended to work in conjunction with other water management models, the reservoir release capacity can be specified at every time step. This approach permits LAWS reservoir releases to be constrained by other in-stream flow requirements that are not explicitly modeled in a LAWS simulation. This capability is accomplished by specifying a LAWS reservoir release capacity as the maximum physical release capacity minus the non-consumptive use flows that are released for other in-stream flow or water quality requirements. Typically, these regulatory releases would be simulated with another model and a daily time series of maximum reservoir release capacities would be computed for a LAWS simulation.

In LAWS, SM reservoir releases are delivered to AMs through an explicitly modeled network of rivers, canals, and drains. The hydraulic properties of these conveyance system features are represented explicitly at user defined reaches along the channels. The LAWS user specifies a maximum flow capacity for each reach and can simulate accretions and depletions in these reaches with simple gain/loss factors. The transit time for water flowing through reaches is also specified by the user.

Deliveries received by the AM are provided to the DMs within the AM region based on the timing and amounts of the DM requests. The DM supply may be composed of a combination of surface water from reservoirs, groundwater pumping and recycled drain water, if available. Prior to delivery to LMs, conveyance losses due to evaporation and seepage are accounted for in the sub-region water budget.

The amount of water delivered to an LM is based on the irrigation system efficiency, the soil water content at the time of the irrigation request and the desired soil water content after delivery. Both surplus and deficit irrigation targets can be simulated. Management of crops or native vegetation under ponded conditions may be simulated with LAWS. The consumptive use of water within each LM is computed by the crop coefficient method to account for plant transpiration as well as soil evaporation. Actual crop transpiration is computed under conditions where either limited or excessive soil water content exists. Drainage occurs when the soil water content is above field capacity and its drainage rate is dependent on soil hydraulic characteristics. Water draining from the soil profile may be captured by drains or become deep percolation to the water table. A request for additional irrigation is triggered when the average soil content in the root zone exceeds a management allowable depletion based on the available water holding capacity of the soil. The amount of the request is based on the irrigation system efficiency and the desired post-irrigation soil moisture content.

Input and Output: LAWS provides users with the capability to evaluate alternative water management strategies based on multiple ***input*** factors including:

- Reservoir and conveyance infrastructure
- Irrigation system characteristics
- Crop types and rotations
- Soil moisture management practices
- Delivery priorities

LAWS simulation ***output*** results can be used to provide spatially accurate water budget information including:

- Consumptive use demands
- Conveyance losses
- Groundwater pumping
- Drain water recycling
- Deep percolation to aquifers
- Soil water content
- Reservoir water account balances
- District deliveries
- Supply shortages

Data Management: LAWS has a native GIS capability built directly into the graphical user interface (GUI). This GIS capability allows users to setup and analyze spatially accurate LAWS simulations across a span of scales ranging from large regional watersheds to sub-regions contained with individual fields. LAWS also provides users with the capability to import imagery, maps, and GIS information developed with commercially available software packages. Furthermore, LAWS has been developed from the Corp of Engineers Water Management System (CWMS) software from which it has inherited a powerful suite of tools to examine model outputs including side by side comparisons of outputs from multiple alternative simulations and animations of spatial and temporal time series results.

Software: LAWS is written in the JAVA programming language to provide platform and operating system independence. The model data sets are stored in several formats including HEC DSS for time series information, XML for model parameters, and various GIS and digital formats for spatial data. The GUI employs proprietary GIS and animation capabilities developed for Reclamation by its subcontractor, Resource Management Associates, using technology initially developed for the US Corps of Engineers in the Corps Water Management System (CWMS) and HEC modeling software systems. An internal release, beta version of the software was completed in December 2005. The software is not currently available for public use as addition R&D is anticipated in 2006. A report describing LAWS as well as methods for using remote sensing and GIS land and soils data to develop model inputs is available.